Whirlwind I

Approximately 35 hours a week of scheduled application time is being divided equally between military and general applications. The aim in connection with general applications is to make the Whirlwind computer available for the solution of worthwhile problems by research workers at MIT and in other academic and industrial organizations. By eliminating any manually set switches and by using one operator to run all programs, it appears to be practical, without loss of efficiency, to use the computer for problems requiring only a few minutes of machine time. The computer has enough time available so that problems can be run without appreciable delay. Computer availability and the number of experienced programmers are about in balance and growing at an equal rate.

Present plans are to attempt to make the preparation of programs an easily learned and readily performed task so that a prospective user can without difficulty set up his own program rather than require the services of an experienced programmer. As steps in implementing this plan, a well-catalogued and easily-used library of subroutines is being built up; explanatory texts describing methods of programming are being developed; and effective methods of having experienced personnel provide advice and assistance to the user are being worked out.

A number of people interested in such diverse problems as digitally-controlled milling machines, missile trajectories, oil reservoir production, ambipolar diffusion, and optical constants of thin metal deposits have already set up successful programs of their own. Further development of the subroutine library and the forthcoming expansion of the present limited (348 registers) storage capacity will greatly facilitate such work.

A second bank of 16 storage tubes has been added to the computer and will soon be available for use. This will at least double the storage capacity used up to the present.

WHIRLWIND I

During the past quarter, Whirlwind I has given approximately 80% useful time. In the period 1 October - 1 December 1952, 375 programs were operated (exclusive of military applications).

To facilitate programming for outside users, a comprehensive new system of service routines is essentially complete, although development and improvement will continue. These routines include provision for a system of floating addresses (permitting the location of any given word or group of words to be designated by any unique letter-number combination), with the final assignment to storage location being made by the computer itself. Interpretive subroutines for extra-precision and floating-point arithmetic place on the machine the responsibility for choice of the appropriate subroutine; the program for such subroutines is written in accordance with a special instruction code in much the usual way. Instructions contained in the interpretive subroutines, instead of being performed directly by the control element, are picked out of storage one at a time by the subroutine and interpreted as desired. The conversion program is so arranged that decimal numbers may be written with a sign followed by as many or as few digits as necessary; the decimal point may be placed anywhere within the number; and integer powers of 2 or 10 may be introduced explicitly into the number as factors. These are then converted to binary numbers in any desired fixed-or floating-point system.

At the present time, installation of auxiliary magnetic-drum storage facilities is nearing completion. The drum will provide storage in 12 groups of 2048 registers each and will allow single word or block transfer to and from electrostatic storage. Average access time to single words or blocks is 8.5 milliseconds within a group or 16 milliseconds to select a new group. The block transfer rate is 64 microseconds per word.

WHIRLWIND I

During the period 1 December 1952 to 1 March 1953, a total of 781 programs (exclusive of military applications) were run.

Of interest among the scientific and engineering problems handled by the computer were: (1) earth resistivity interpretations, MIT geology and geophysics department, (2) deuteron binding energy and wave functions, MIT physics department, (3) transient aerodynamic heating of a flat plate, aero-elastic and structures laboratory, (4) Lawley's method of factor analysis, characteristic vectors (modified); educational testing service, research department, (5) optical properties of thin metal films, MIT chemistry department.

A comprehensive system of service routines using perforated paper tape as auxiliary storage has been in use during the above period of time. However, further development and refinement of this system continues. In particular the system has now been modified to use two magnetic tape units as auxiliary storage. The use of the magnetic drum as further auxiliary storage is being studied. These forms of auxiliary storage greatly reduce the amount of time taken by conversion.

In addition to the features discussed in the January 1953 Newsletter, the comprehensive system now includes the automatic selection of output routines. The programmer obtains the desired form of output by writing at the proper point of his program a sample number preceded by three letters which indicate essentiallv the output medium required (typewriter, punch, magnetic tape, or numeriscope).

A course is now being offered monthly to provide qualified persons with necessary training for programming on WWI. In addition, a seminar is being conducted for discussion of advanced programming techniques.

WHIRLWIND I

The Whirlwind I computer continues to be used for scientific and engineering problems for about 30 hours per week. A total of 115 such programs were run during the period March 1 June 1, 1953. Most of these were parts of long-range problems introduced during the previous quarter.

Testing of the auxiliary-magnetic-drum (discussed in previous issues of the Newsletter) is complete and the unit is available for use by the programmers. The read-in program is now stored on the magnetic drum and is read into electrostatic storage when read-in is requested. Reliability studies of the drum system will continue during the summer.

The Scientific and Engineering Computation Group are determining suitable means of incorporating the magnetic drum into a conversion scheme, designed to eliminate, to a large extent, the logical distinction between storage on the drum and storage in the computer's electrostatic storage system. Suitable post-mortem and mistake-diagnosis programs will be considered an integral part of this system.

Installation of the second bank of tubes in electrostatic storage has been completed and the system is operating reliably.

Extensive use has been made of delayed printing using magnetic tape. Data from the computer is stored rapidly on the tape and, at a convenient time later, is printed at a slower speed without interfering with computer operation.

Photographs are being taken of scope displays so that larger amounts of data can be read out and analyzed. Operation of the camera is controlled by the computer program.

WHIRLWIND I

Applications

Since June 1 the following problems have been initiated by the Scientific and Engineering Computation (S&EC) Group for solution on the Whirlwind I Computer:

No. 137. Investigation of Atmospheric Turbulence

No. 138. Spheroidal Wave Functions

No. 139. Calculations of the Shape of Nuclear-Magnetic-Resonance Absorption Lines

No. 142. Study of Shock Waves (a two-dimensional grid of concentrated masses subjected to impulsive loads)

No. 143. Vibrational Frequency Spectrum of a Copper Crystal

These problems were in addition to the long-range problems reported in the previous Digital Computer Newsletter.

Summer Session

During July the S&EC Group developed an experimental computer logic which was used in a two-week Summer Session course at MIT (August 24 - September 4) entitled "Digital Computers and their Applications." This logic involved the physical equipment of Whirlwind I and made use of interpretive routines for programmed extra precision and floating-point arithmetic, cycle counting, input and output, together with facilities for program conversion, mistake recognition, and post-mortem diagnosis. The course was attended by 106 persons representing 67 organizations.

ACM Meeting

The summer conference of the Association for Computing Machinery was held at MIT on September 9, 10, and 11. During the meeting, the Digital Computer Laboratory was open for inspection and 239 visitors were recorded.

Magnetic-Core Memory

A new internal high-speed memory utilizing magnetic cores has replaced electrostatic storage in Whirlwind I. The storage capacity of the new memory is the same as the old (2048 registers), but performance tests have indicated that magnetic cores will greatly reduce maintenance time as well as increase the computer's operating speed. The next issue of the Newsletter will contain detailed information on the operation of this system.

WHIRLWIND I

Applications

During the past three months, the following problems were initiated by the Scientific and Engineering Computation (S&EC) Group, in conjunction with various departments at MIT, for solution on Whirlwind I:

Problem No.	Title
144	Self-Consistent Molecular Orbitals
145	Evaluation of Second-Order Temperature Diffuse Scattering from Zinc
146	Largest Eigenvalue of Real, Symmetric Matrix
147	Energy Bands in Crystals
148	Elliptic Boundary-Value Problems
149	Digital Methods of Detecting Signals in Noise
151	Machine Programming and Mathematical Analysis of the General Game of NIM
152	Diffusion in an Oxide-Coated Cathode
153	Gust Response; Simultaneous Linear Integro-Differential Equations
155	Synoptic Climatology
156	Evaluation of the Reflection Coefficient in a Semi-Infinite Rectangular Wave Guide
157	Rectangular Matrix Multiplication

Work was also done on other problems described in previous issues.

Magnetic-Core Memory

The excellent performance record which the new magnetic-core memory has established during the five weeks Nov. 2 to Dec. 6 is encouraging. Only one parity alarm (indicating a failure to get correct information from memory) was made during approximately 700 hours of computer operation. This figure is in contrast to the average of 2 alarms per day encountered when electrostatic storage was part of the Whirlwind I system. The comparison is more impressive when one considers that the access time of magnetic-core memory is 8 microsec, whereas electrostatic storage required an average of 30 microsec for the equivalent operations.

Applications

During the past three months, the following problems were initiated by the Scientific and Engineering Computation (S&EC) Group, in conjunction with various departments at MIT, for solution on Whirlwind I:

Problem No.	Title
154	Magnetic Susceptibility Evaluation
158	Relay Servo Response
159	Water Use in a Hydroelectric System
160	Similarity Transformation of a Matrix
161	Response of Mass-Plastic Spring System to Transient Loading
162	Determination of Phase Shifts from Experimental Cross-Sections
163	Ferrite Phase Shifters in Rectangular Wave Guide
166	Construction and Testing of a Delta-Wing Flutter Model
167	Products of Batch Distillations with Holdup
168	Indicial Downwash Behind a Two-Dimensional Wing
169	Utilizing a General-Purpose Digital Computer in Switching Circuit Designing

Work was also done on other problems described in previous issues.

The development of the comprehensive system of routines for the input conversion of suitably prepared punched paper tapes has continued. These routines automatically provide a program with suitable programmed-arithmetic, cycle-counting, and output facilities. The original system, which has been used successfully for more than a year, is now being revised to expand the facilities available.

Academic Program

The following seminars on computing machine methods were held:

Dec. 1, 1953 "An Interpretive Program for Mathematical Equations"
Dr. J. H. Laning, Jr., Instrumentation Lab., MIT

Dec. 15, 1953 "A Mistake Diagnosis Routine for WWI"
D. T. Ross, Servomechanisms Lab., MIT

Jan. 12, 1954 "Some Aspects of the Numerical Integration of Ordinary Differential Equations"
Dr. Per-Olav Löwdin, University of Uppsala, Sweden

Feb. 23, 1954 "Survey of Commercially-Available Digital Computers"
Dr. F. M. Verzuh, Director Statistical Services, MIT

A series of seminars on advanced programming techniques has been organized and presented by members of the Digital Computer Laboratory staff. These seminars provide an extension of the basic ideas that are presented in the special two-week introductory programming course offered to persons who have been unable to take the more formal MIT courses but who desire to carry out the solution of approved problems.

Plans are being made for two Special Summer Programs on digital computers to be presented during the 1954 Summer Session. One two-week program (MIT subject 6.531) will describe the planning and coding needed in using stored-program general-purpose digital computers, with special reference to business applications. The other program (6.532) will provide a one-week series of lectures and discussions on automatic coding techniques for a group of experienced computer programmers.

WHIRLWIND I

Applications

During the past 3 months, the Scientific and Engineering Computation Group, in conjunction with various departments at MIT, processed 62 problems for solution on Whirlwind I. These problems are described in the Project Whirlwind Summary Reports submitted to the Office of Naval Research.

A procedure has been developed to eliminate most of the need for manual intervention in "reading in" the tapes for different problems during a computing period. The procedure makes use of a specially prepared "director" tape which communicates with the computer through a separate input reader. The various problem tapes, together with suitable post-mortem-request tapes, are spliced together in the proper sequence. The complete run is then effected under the control of the director tape by a single push on the read-in button.

Systems Engineering

A newly written program locates and identifies troubles in WWI terminal equipment. The diagnosis printed out by the computer includes the nature of the trouble and its location and, sometimes, identifies by number the tube in the offending circuit. (This program is applicable only to terminal equipment, and it does not appear that its use can be further extended.)

In a recent test, a tube previously removed from the computer because of low emission was placed in socket V08 of the plug-in unit in Bay 2, Jack 10, of the drum system; in a few seconds the direct typewriter printed:

d 0-7 fail g O ck write gate ampV08b2j10

In plain English, digits 0 through 7 failed in Group O, the cause being the write-gate amplifier tube V08 in Bay 2, Jack 10.

The program works on the assumption that each trouble has a unique set of symptoms. If the program ever runs into a set of symptoms which is not in its catalogue, it gives an indication of these symptoms. Later, when the trouble is found by "old fashioned" means, it, too, can be included in the catalogue of troubles.

Academic Program

The principal course on machine computation being offered at MIT in the fall of 1954 was 6.25, Machine-Aided Analysis, a survey of computing techniques intended largely for seniors in Electrical Engineering. This subject, first offered in the spring of 1954, had a fall-term enrollment of about 55 seniors and graduate students. Practice problems were planned to allow each student to use both a REAC and the Whirlwind I computer (simulating the hypothetical Three-Address Computer developed for the 1954 Summer Session). Exercises using desk calculators and a card-programmed calculator which were included in the first presentation of the course were eliminated in this second presentation to permit more time for studying techniques of problem and error analysis.

WHIRLWIND, MIT (December 1954; January and February 1955)

Applications

During the past 3 months, the Scientific and Engineering Computation Group, in conjunction with various departments at MIT, processed 76 problems for solution on Whirlwind I. These problems are described in the Project Whirlwind Summary Reports submitted to the Office of Naval Research. Of these problems, 32 are for academic credit (1 for a bachelor's degree, 6 for master's degrees, and 25 for doctor's degrees); the results of 12 are expected to be included in reports submitted for publication in technical journals.

Routines available in the comprehensive system have been extended to include curve plotting, axes display, axes calibration, and alphanumerical display. The desired routine is assembled in response to an appropriate pseudo-code (e.g., SOC a2 will call in a routine that will plot on the oscilloscope a point—Scope Output Curve—whose x-coordinate is stored in register a2 and whose y-coordinate appears in the accumulator).

Systems Engineering

In September 1954, the procedures for gathering and evaluating data on the operation of the Whirlwind I computer system were revised to permit more comprehensive analyses of system reliability. In general, the new procedures provide more complete data on all computer stoppages and a biweekly review and summary of these stoppages. In the summary, each failure is classified to show its cause or principal symptom as well as to show whether it should be charged against the system or directly attributed to installation of new equipment or to modification.

In the 20-week period since these records were initiated the following data have been obtained:

Total computer operating time	2675 hours
Total number of failure incidents	244
Average uninterrupted operating time between incidents	10.6 hours
Average time to locate and repair each failure	22.8 minutes

These data reflect the total experience on the entire system which contains approximately 6500 tubes (8000 cathodes) in the central computer and about 4200 tubes (5000 cathodes) in its terminal equipment. They cover operations on a 24-hour-per-day basis approximately 6 days per week. Since only a fraction of the terminal-equipment facilities are required during portions of the computer time, failures in the sections not in use may or may not actually interrupt system operation. Failures which do not cause interruptions, however, must be considered in order to obtain an accurate picture of system performance. In obtaining the averages given above, such a failure was considered to have caused a time loss equal to the average actual lost time for that class of failure.

The amount of preventive maintenance required has decreased as new installation programs were completed. For the past few months, time spent on preventive maintenance has averaged about 1.25 hours per day.

Academic

MIT Course 6.535, Introduction to Digital Computer Coding and Logic, a discussion of selected topics in programming, logical design, and applications of large-scale digital computers, is being offered during the spring of 1955. The course has an enrollment of 65 seniors and graduate students from the engineering and industrial-management curricula.

Project Whirlwind staff members have participated in seminars on machine methods of computation, numerical analysis, and operations research.

Applications

During the past three months, the Scientific and Engineering Computation Group, in conjunction with various departments at M.I.T., processed 66 problems for solution on Whirlwind I. These problems are described in the Project Whirlwind Summary Reports submitted to the Office of Naval Research and cover some 15 different fields of applications. The results of 22 of the problems have been or will be included in academic theses. Of these, 19 represent doctoral theses, two master's and one electrical engineering thesis. Thirty-seven of the problems have originated from research projects sponsored at M.I.T. by the Office of Naval Research.

Even though no major modifications were introduced into the comprehensive system of service routines, the development of new coding techniques by the S & EC Group was extended by the development of translation programs for M.I.T.'s Numerically Controlled Milling Machine. The new coding techniques are also useful to members of the Servomechanisms Laboratory in coding for the UNIVAC Scientific 1103 computer.

Academic

Course 6.535, Introduction to Digital Computer Coding and Logic, a discussion of selected topics in programming, logical design and applications of large scale digital computers, was offered at MIT during the spring of 1955. The course included the solution of a programming problem on a simplified single address computer simulated by Whirlwind I. Among the problems solved by the class members were the solution of simultaneous linear equations, integration of differential equations, and the economization of power series. The total enrollment was 55 seniors and graduate students (from both the engineering and industrial management curricula).

Project Whirlwind staff members have been participating in seminars on machine methods of computation, numerical analysis, and operations research.

Systems

A. Revisions in the Marginal Checking Procedures for the Drum Systems

The programmed-marginal-checking facilities have been expanded to include additional terminal equipment. Previously, this equipment was checked by taking manual margins during specially assigned maintenance periods. The marginal-checking equipment was modified to include the drum equipment in the daily programmed-marginal-checking routines. In the past, check program cycle for this type of terminal equipment has been long compared to the existing voltage variation cycle. It is now possible to select the marginal-checking equipment in a special mode which will hold a preset excursion for an amount of time determined by the program.

A consolidated test program containing nine routines has been written for the drum system. The proper choice of program techniques and assignment of variation lines has reduced the checking time enough to make it practical to include the program as a part of the daily marginal-checking routine. The drum system, containing approximately 5,500 cathodes, is now checked in one half of the hour scheduled for daily system maintenance.

B. Whirlwind Computer Reliability

The following data pertains to the most recent 13 and 33 weeks of operation:

	13 Week Period	33 Week Period
Total Computer operating time	1923 hours	4598 hours
Total lost time	65.2 hours	157.8 hours
Total number of failure incidents	170	410
Average uninterrupted operating time between incidents	10.9 hours	10.8 hours
Average time to locate and repair each failure	23 minutes	23.1 minutes
Percentage operating time usable	96.6%	96.6%

WHIRLWIND I (JULY, AUGUST AND SEPTEMBER 1955)

Applications

During the past 3 months, the Scientific and Engineering Computation Group, in conjunction with various departments at MIT, processed 94 problems for solution on Whirlwind I. These problems are described in the Project Whirlwind Summary Reports submitted to the Office of Naval Research and cover some 22 different fields of applications. The results of 18 of the problems have been or will be included in academic theses. Of these, 12 represent doctorate theses, 1 Engineering, 4 Master's and one Bachelor's. Twenty-one of the problems have originated from research projects sponsored at MIT by the Office of Naval Research.

Academic

The Digital Computer Laboratory programming course was given once during this quarter. The course includes the following topics: Relative addresses, temporary storage, floating addresses, preset parameters, programmed arithmetic, cycle counters, buffer storage, automatic output, post mortems, and multipass conversion. The text for the course is a programmer's manual written by staff members of the S&EC Group. The 23 students enrolled during this quarter represented the following groups: Department of Nuclear Engineering, Nuclear Metals Laboratory, Meteorology Department, Physics Department, Aero Physics Laboratory,

Biology Department, Department of Civil Engineering, Harvard Business School, Lincoln Laboratory Office of Statistical Services, and the Rand Corporation.

Systems

Magnetic Drums

The interlace on the auxiliary section of the buffer drum has been changed to provide more rapid access to drum storage. The computer may now read or record blocks of information at the rate of one word every 32 microseconds. The former rate was one word every 64 microseconds.

The control systems for both drums have been modified to permit the selection of a new mode of operation. The programmer, by adding 1000 (octal) to the present drum orders, may select the drum as a consecutively addressed storage medium with no discontinuities at the end of each group. The Group Selection Register (GSR) has been made a counter which is added to by the end carry from the Storage Address Register (SAR). The SAR end carry to GSR is gated by digit 6 of the in-out switch.

Magnetic Tape

In several instances valuable information recorded on magnetic tape has been destroyed by accidental recordings over this information. A system has been installed to allow the three printout units to be locked in the read mode by means of toggle switches located on their control panels. The computer may sense an intervention bit to determine whether these switches have been thrown or whether the units are ready to record.

Power Supplies

A spare filament alternator has been obtained and the installation work necessary for connecting it into the system is in progress. The control system will be such that the alternator may be used to replace either of the two alternators now in service by operating one or two toggle switches. A system for substituting a motor-generator set for one of the d-c supplies is being developed.

Polaroid Land Camera

A Crown-Graphic camera with a Polaroid Land-camera back has been mounted in the control room for photographing the indicator lights. The photographs may be used in place of manual recordings of the lights. This system provides a sure, fast accurate means of gathering trouble-location information.

WHIRLWIND I (FOR APRIL, MAY, AND JUNE 1956)

Applications

During the past 3 months, the Scientific and Engineering Computations Group, in conjunction with various departments at MIT, processed 95 problems for solution on Whirlwind I. The problems are described in the Project Whirlwind Summary Reports submitted to the Office of Naval Research and cover some 20 different fields of applications. The results of 32 of the problems have been or will be included in academic theses. In these 32 problems, there are represented 25 doctoral theses, 3 Naval Engineer's, 5 master's, and 4 bachelor's. Twenty-six of the problems have originated from research project sponsored at MIT by the Office of Naval Research.

Academic

There are a number of graduate subjects in automatic computation, numerical analysis, and now electronic data processing, offered at MIT. The following is a table of subjects directly related to machine computation. The number of students is a total of the enrollment for both fall and spring terms.

Course	Description	Year	Instructor	# of Students
2.215	Methods of Engineering Analysis	G	S. H. Crandall	18
6.25	Machine-aided Analysis	4	W. K. Linvill	153
6.535	Digital Computer Coding and Logic	G	D. N. Arden	97
6.538	Electronic Computational Laboratory	G	F. M. Verzuh	26
6.54	Pulsed-Data Systems	G	W. K. Linvill	60
6.567	Switching Circuits	G	S. H. Caldwell	48
6.568	Switching Circuits	G	S. H. Caldwell	30
15.542	Management Information Systems	G	R. H. Gregory	22
M 39	Methods of Applied Mathematics	G	F. B. Hildebrand	253
M 411	Numerical Analysis	G	F. B. Hildebrand	45
M 412	Numerical Analysis	G	F. B. Hildebrand	16

Systems

Since 1954 the MIT Servomechanisms Laboratory has been using the WWI manual intervention and display equipment in the development of high-speed data reduction techniques. In order for them to expand their research into computer applications, it was essential that more versatile manual inputs be made available on the WWI computer. Besides requiring additional on-off switches, many of the new programs will be so complex and will require so many parameters that the only reliable way to instruct them will be to use specially designed mnemonic

languages and translation programs. In order to have this general language structure available on a manual intervention basis, it is necessary to have a keyboard such as a Flexowriter for direct input to the computer.

The MIT Scientific and Engineering Computations Group have contemplated the following applications for the new facility:

1. Demonstration programs would be a great deal more effective if this form of input were available for control purposes.

2. Typewriter input for Comprehensive System Flexowriter and post mortem request tapes. Short program modifications and Post Mortem requests can presently be inserted in the insertion registers. However, errors are easily made because the required vocabulary is awkward. A typewriter input facility would make available a normal mnemonic vocabulary for such purposes.

3. Experimental use of a typewriter facility for direct operator control of the computer. Here we would consider using the typewriter to replace the button-pushings required of the operator during normal operations. Vocabulary similar to that of Director tapes and performance requests would be devised for these purposes. This could easily prove to be an extremely convenient and efficient method of computer operation.

The new input installation will be available for use by 4 July 1956. Much of the information to be inserted via the keyboard will be the same as is now introduced via a free running photoelectric tape reader using punched paper tapes. The keyboard input will also be treated as a free running device, i.e., selection of the facility by the computer may be followed by an arbitrary number of read instructions, each of which reads the next character which has been struck on the keyboard. The total equipment requirements amount to 15 relays and 20 tubes.

<u>WWI RELIABILITY</u> 9 March - 31 May 1956

The following is the WWI Computer Reliability for the past quarter:

Total Computer Operating Time in Hours	1915
Total Time Lost in Hours	24.3
Percentage Operating Time Usable	98.7
Average Uninterrupted Operating Time Between Failure Incidents in Hours	28.6
Total Number of Failure Incidents	66
Failure Incidents per 24-Hour Day	1.2
Average Lost Time Per Incident in Minutes	22
Average Preventive Maintenance Time per Day in Hours	1.8

WHIRLWIND I - M.I.T. - CAMBRIDGE, MASS.

Applications. During the last 3 months of 1957, the Scientific and Engineering Computation Group, in conjunction with various departments at MIT, processed 68 problems for solution on Whirlwind I. The problems are described in the Project Whirlwind Summary Report submitted to the Office of Naval Research and cover some 18 different fields of application. The results of 20 of the problems have been or will be included in academic theses. In these 20 problems, there are represented 17 doctoral theses, 5 master's and 1 bachelor's. Twenty-two of the problems have originated from research projects sponsored at MIT by the Office of Naval Research.

Systems Reliability. The following is the WWI Computer Reliability Record for the last quarter of 1957:

Total Computer Operating Time in Hours	1836.5
Total Time Lost in Hours	35.8
Percentage Operating Time Usable	98.1
Mean Free Time Between Failure Incidents (in hours)	23.6
Total Number of Failure Incidents	84
Failure Incidents per 24 Hour Day	1.1
Average Lost Time per Incident in Minutes	25.2
Average Preventive Maintenance Time per Day (in hours)	2.3

Reorganization. The previously discussed plans for the installation of the Type 704 Computer, in the new Karl T. Compton Center, are proceeding as scheduled. It is expected that the computer will be in operation by April 1957, at which time many of the staff members will be spending most of their time working on the 704 computer.

Sometime during the summer Whirlwind will be turned over to Lincoln Laboratory for full-time use. The exact date of this has not been determined, since it depends on work being done on Whirlwind.

COMPUTATION CENTER - M.I.T. - CAMBRIDGE, MASS.

The MIT Computation Center, which was established in July 1956, is an inter-departmental activity located in the new Karl T. Compton Laboratory (Building 26). The principal objective of the Center is to increase the number of students, staff members, and scientists qualified to use modern computing machines to further their research efforts. The Center is an activity which has many assets: qualified staff, modern computing equipment, and a brand new physical plant. The participating personnel in the Center program are located at MIT, IBM, or one of the participating New England Colleges or Universities. Specifically, the Center represents a cooperative activity involving MIT, the IBM Corporation and, at present, 25 New England Colleges and Universities.

An active participation by the staffs of the New England Colleges in the Computation Center program was initiated by the appointment of 24 Research Assistants and Associates at these institutions during the academic year 1956-1957. These appointees provide active liaison between the staff at the Center and the students and staff at their individual institutions. Appointments of this type will be made each year -- to insure a widespread and dynamic participating program.

Physical Plant. The physical plant of the MIT Computation Center consists of 18,000 square feet located in the recently erected Karl T. Compton Laboratory. Specifically, the Center occupies part of the basement, the entire first floor, and part of the second floor of the Compton Laboratory. In addition, a two-story annex is used to house the IBM Type 704 Electronic Data Processing Machine and the associated Electric Accounting Machine equipment.

The first floor contains adequate space for the headquarters staff, the operations staff (analysts, programmers, machine operators, etc.), IBM Institutional Representatives, New England University Research Assistants and Associates, MIT Research Assistants and Associates, classroom and seminar room, as well as the 704 computer. The basement provides space for the EAM machines, the systems research laboratory, dark room facilities, the electrical power plant, and the air conditioning equipment. The second floor provides space for the programming research staff, the visiting professors, and the library and document room. All this area has been furnished in a first-class manner to facilitate the progress of research at the Center.

Computer Installation. Although the 704 Computer was installed sometime ago, there have been unavoidable delays in the completion of the physical plant and associated air conditioning equipment, which prevented earlier operation of the machine. As a matter of fact, it is now expected that the machine will be placed into three shift operation on June 10, 1957. It is therefore too early to make any definite statements regarding the reliability of the machine, or of the results obtained therefrom. Succeeding news reports will contain information of this type.

As noted from previous announcements, the Whirlwind I computer is becoming less used in the Scientific and Engineering Computation Group problems and more actively identified with the Lincoln Laboratory. Accordingly the Whirlwind I reliability figures will be discontinued.

FX-1—LINCOLN LABORATORY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, LEXINGTON 73, MASS.

The fastest digital computer ever built is now in operation at the M.I.T. Lincoln Laboratory in Lexington, Massachusetts. Known as the "FX-1", this new computer is in every important respect a working model for a new generation of machines, ten times faster than any computers in general use today. The significance of the new machine lies not in its size or capacity, which are modest, but in the unusually high speed at which it operates, and in new construction techniques designed especially for high frequency operation.

It is the first machine with a main memory using thin magnetic films in place of ferrite cores for high-speed, random-access storage. FX-1 is designed to be a complete, small-scale, general-purpose computer, for realistic tests of fast logic circuitry and magnetic film storage in system operation.

In specifying the speed of a computer, there are two items of particular interest: (1) the time required to read a computer word out of the memory and to write in a new word (the "read-write cycle time"), and (2) the speed of the logic circuits, which may be specified by the rate of the timing pulses which govern the operation of these circuits (the "clock rate"). Both of these items are noteworthy in the FX-1, since in both instances the new machine is substantially faster than the most advanced commercial computers of today.

Memory

The read-write cycle time for the central memory of the Lincoln FX-1 is 0.3 microsecond. The fastest main memories in machines today have cycle times that generally range from 2 to 12 microseconds. These memories use magnetic cores for storage, following techniques developed by Lincoln Laboratory some years ago, without which the large, high-speed, general-purpose computers of today could not have been developed. The largest core memory in existence, with a capacity of more than 2,500,000 bits, was built by Lincoln some four years ago and is part of the older Lincoln TX-2 computer. This large core memory has a read-write cycle time of 6.5 microseconds.

Also a part of TX-2 is a small fast memory using thin magnetic films, the first such memory to be installed in a computer. In regular use for almost two years, this magnetic film memory operates in TX-2 with a cycle time of 0.8 microsecond, consistent with its functions in the computer itself; in bench tests, a cycle time of 0.4 microsecond was attained, limited by the performance of the transistors that were available at the time the memory was built.

The faster magnetic film main memory in the new FX-1 profits from improved transistors, circuitry and fabrication techniques that have been developed in the intervening two-year period. Various arrays of magnetic film memory elements deposited on thin glass plates are possible. Circular spots were used in the small TX-2 memory and small rectangular spots are used in FX-1.

The initial FX-1 memory has a capacity of 256 words of thirteen bits each, but provision has been made to increase the initial capacity by a factor of four. This memory is large enough to serve the purpose of FX-1, to provide a realistic test of fabrication and operating techniques on a practical scale, and at the same time to provide sufficient storage to enable the machine itself to be useful for some practical purposes. Because of the high speed of the logic circuits and the short cycle time of the memory, the FX-1 can match the performance of considerably larger conventional machines.

The memory employs printed-circuit wiring on a flexible sheet of resin-impregnated glass-fiber cloth. The arrays of memory elements, deposited on thin glass backing plates, are positioned on the wiring so that each magnetic-film element rests on the intersection of two perpendicular leads on the wiring sheet. When all the memory element arrays are in place on the lower half of the wiring sheet, the upper half is folded over to make the completed memory. This single unit contains the 256-word, 3328-bit memory of the FX-1 computer.

Circuits

The logic circuits in Lincoln's new FX-1 operate at an effective clock rate of 50 million pulses per second, ten times faster than TX-2 and other large machines currently in operation, and four times the rate of the fastest commercial machine disclosed to date. This increase in speed is made possible by high-speed switching transistors developed under subcontract, with the collaboration of Lincoln's Computer Components Group, and now in commercial production. The fastest commercial machines now in common use have clock rates comparable to that of the TX-2.

Approximately 3000 transistors are used in the FX-1; this is about the same number as in the Lincoln TX-0 computer, built about five years ago, which was the same forerunner of the TX-2 computer in use at the Laboratory today. TX-2 has some 30,000 transistors in the central machine, and one of the large new commercial machines will have as many as 200,000.

The FX-1 logic circuits are packaged in plug-in units that have been designed for compactness, as well as being particularly suited to high frequency operation. Components are mounted on or between two printed-circuit boards that are an integral part of the mechanical framework of the plug-in unit. The plug-in units are mounted in trays that hold up to 20 units each and themselves plug into the computer frame. Plug-in units with closely related functions are located on a common tray to simplify interconnections.

Approximately 325 plug-in units of 12 standardized basic types are used in the FX-1. They are mounted in 24 trays, of 13 different types. The entire computer, with power supplies, occupies only three relay racks.

Some of the trays in the FX-1 are fabricated by a developmental technique called "plated-circuit" wiring, as contrasted with "printed-circuit" wiring for the plug-in units and conventional point-to-point soldered wiring for most of the trays. The plated-circuit trays employ two layers of etched wiring sandwiched on either side of a central, copper ground-plane. Wiring of this type behaves like strip transmission line, with uniform impedance characteristics that should simplify and improve circuit performance at high frequencies. Interconnections from one layer of wiring to another are made by plated-through holes rather than by soldering. The FX-1 is a good vehicle in which to test this type of wiring, where it is an important factor in the performance of high-frequency circuits.

The FX-1 computer was designed and built by the Digital Computers Group in the Information Processing Division of the M.I.T. Lincoln Laboratory, with assistance from Lincoln's Computer Components Group. Lincoln Laboratory is a center for research, operated under Air Force contract by M.I.T., with the joint support of the U.S. Army, Navy, and Air Force.

COMPUTER DEVELOPMENT— LINCOLN LABORATORY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, LEXINGTON 73, MASS.

Computer development at the M.I.T. Lincoln Laboratory had its origin in the M.I.T. Digital Computer Laboratory that grew up around Whirlwind I, the first modern, high-speed, general-purpose digital computer. Planning for Whirlwind began in 1946, and the machine was put into full-scale operation late in 1951 as the largest and fastest digital computer in existence at that time. The design and construction was sponsored by the Office of Naval Research.

Lincoln Laboratory was founded in 1951, at the request of the Army, Navy, and Air Force, to effect urgently needed improvements in air defense. The rapid evolution of computer technology during the period 1946-1951, stimulated to a considerable degree by the development of Whirlwind, made it possible to demonstrate the feasibility of a semi-automatic system to process radar data, generate displays, and guide defensive weapons. The realization of such a system for continental air defense was the major preoccupation of Lincoln Laboratory during its first 8 years of existence. The result is the SAGE (Semi-Automatic Ground Environment) System, the largest data-processing system ever attempted, now in operational use by the Air Force. This system employs some 70 large digital computers (designated AN/FSQ-7) and a much larger number of specialized data processors. All this equipment was originally designed at Lincoln Laboratory, with further engineering development and production carried out by various manufacturing contractors.

Soon after Lincoln Laboratory was founded, the M.I.T. Digital Computer Laboratory became the Digital Computer Division of Lincoln, and Lincoln assumed primary responsibility for the use and further development of Whirlwind I. In 1953-54, Whirlwind was a primary test vehicle for the first 1024-word ferrite core memory, developed to supplant the electrostatic storage tubes previously employed for high-speed storage. The ferrite core memory is an M.I.T. contribution that has proved to be of fundamental importance to modern digital computer technology. The first core memory in Whirlwind had a capacity of 1024 16-bit words, with a read-write cycle time of 10 microseconds.

Also, in 1953, the Memory Test Computer (MTC) was placed in operation, both as a memory test vehicle and as a general-purpose computer in its own right. In 1954, a 4096-word core memory was installed in MTC, with a read-write cycle time of about 5 microseconds, twice as fast as the central core memory in Whirlwind.

The Lincoln TX-0 computer was put into operation in 1956. This was the first Lincoln computer in which transistors (about 3000) completely supplanted vacuum tubes in the logic circuits. It has a 5-megapulse clock rate, two and a half times faster than that of Whirlwind or MTC. TX-0 served as a test bed for evaluation and development of transistor circuitry and of the largest core memory ever built, with a capacity of about 2.5 million bits and a cycle time of 6.5 microseconds. This memory was developed and built by Lincoln as a prototype for large memory units produced by IBM for the SAGE System. At the time there were no transistors that could supply the currents necessary to drive this core memory; hence this memory is vacuum-tube driven and uses about 1000 tubes.

Direct successor to TX-0 is the larger TX-2 computer. Completed in 1958 and still in active use, the TX-2 has about 30,000 transistors in the central machine. Both TX-0 and

TX-2 use the same general circuit design and operate at the same clock rate (5 megapulses per second).

The large core memory is now the main memory of TX-2, but two smaller auxiliary memories are also worthy of note. In 1959, a transistor-driven core memory (TDCM) was put into operation, with a capacity of 150,000 bits (4096 36-bit words) and a cycle time of 4.5 microseconds. In that same year, a small memory using thin magnetic films was installed in TX-2, the first such memory to be used in an operating computer. Very small but very fast, this magnetic film memory has a capacity of only 320 bits; however, it operates with a cycle time of 0.8 microsecond in TX-2, and has been bench tested to 0.4 microsecond.

It was at the beginning of 1959 that the SAGE-oriented parts of Lincoln's computer work were transferred to the newly-formed MITRE Corporation. The advanced computer development groups remaining at Lincoln were incorporated into the newly established Information Processing Division, with which they are presently affiliated. It is these groups that have been concerned with the development of the new FX-1 computer.

Throughout the years of its computer development, Lincoln has consistently supported and stimulated the development of higher frequency transistors, through subcontracts with transistor manufacturers. Several generations of transistors developed under this program are now commonly available and in general use. It was the 2N240 and 2N293 transistors that made possible the TX-0 and TX-2 computers, and it is the 2N769 (that has now been used at Lincoln for almost two years) that has made possible the development of the new FX-1.

No mention is made here of the many other digital computers and information processing systems that have been built for special purposes by various groups in the Laboratory. The discussion has been restricted to a selected few, general-purpose machines in order to illustrate the chronological increase in speed and capability of memories and logic circuitry. Tables I to III summarize this evolution in greater detail from different aspects.

Table I. Random-Access Memories in Lincoln Laboratory Computers

Year	Machine	Type	Bits	Read-Write Cycle Time (microseconds)
1953	Whirlwind I	ferrite core	16,000	10
1954	MTC	ferrite core	65,000	5
1956	TX-0	ferrite core	1,250,000	6.5
1958	TX-2	ferrite core	2,500,000	6.5
1959	TX-2 (TDCM)	ferrite core	150,000	4.5
1959	TX-2	magnetic film	320	0.8
1961	FX-1	magnetic film	3,300	0.3

Table II. Effective Clock Rates of Lincoln Laboratory Computers

Year	Machine	Number of Cathodes or Transistors in Central Machine	Effective Clock Rate (megapulses/sec)
1950	Whirlwind I	5,000 C	2
1953	MTC	5,000 C	2
1956	TX-0	3,000 T	5
1958	TX-2	30,000 T	5
1961	FX-1	3,000 T	50

Table III. Representative Operating Characteristics of Three Lincoln Laboratory Computers

Characteristic	Whirlwind I (1949-53)	TX-2 (1958)	FX-1 (1961)
Basic word length (bits)	16	36	12
Effective clock rate (megapulses per second)	2	5	50
Speed (average operations per second)	30,000	120,000	2,000,000
Memory			
Core (bits)	16,000	2,500,000	0
Read-write cycle time (microseconds)	10	6.5	-
Magnetic film (bits)	0	320	3,300
Read-write cycle time (microseconds)	-	0.8	0.3
Components			
Cathodes	5,000	1,000	0
Transistors	0	30,000	3,000
Power (kilowatts)	150	20	5